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INPLASY

Effects of Thermal Processing on Protein Digestibility and Protein Quality of Edible Insects for Human Consumption: A Systematic Review Protocol

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ADMINISTRATIVE INFORMATION

Support - There is no external funding of this systematic review.

Review Stage at time of this submission - Formal screening of search results against eligibility criteria.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 29 August 2026 and was last updated on 29 August 2026.

INTRODUCTION

Review question / Objective Review question: What are the effects of thermal processing on protein digestibility and protein quality of edible insects intended for human consumption compared with raw or unprocessed insects or insects subjected to alternative processing methods?
Objective: To systematically evaluate the effects of thermal processing techniques on protein digestibility and protein quality of edible insects intended for human food.

Rationale Edible insects are increasingly recognized as a promising alternative source of dietary protein because of their high protein content, favorable amino acid profiles, and potential environmental advantages compared with conventional animal-source foods. Before human consumption, edible insects are commonly subjected to processing to improve their safety, palatability, sensory characteristics, and shelf life. Thermal processing methods, including boiling, steaming, roasting, frying, baking, and other heat treatments, are among the most commonly applied techniques and may substantially alter the structural and physicochemical properties of insect proteins.
Thermal processing may have both beneficial and detrimental effects on protein nutritional value. Heat-induced protein denaturation may increase the accessibility of digestive enzymes and improve protein digestibility, while thermal treatment may also reduce certain antinutritional factors that interfere with protein digestion. Conversely, excessive heating may promote protein aggregation, oxidation, cross-linking, and Maillard reactions, potentially reducing protein digestibility and the availability of essential amino acids. These effects may vary according to insect species, processing method, temperature and duration of treatment, and methods used to assess protein digestibility and quality. Although experimental studies have investigated these effects using in vitro and in vivo approaches, their findings vary across insect species and processing conditions, making the overall impact of thermal processing on

the nutritional quality of edible insect proteins unclear.

A systematic synthesis of the available evidence is therefore needed to clarify the effects of thermal processing on protein digestibility and protein quality of edible insects intended for human consumption. By comparing thermally processed insects with raw or unprocessed insects or insects subjected to alternative processing methods, this systematic review will evaluate the direction and magnitude of changes in protein digestibility and quality across different thermal treatments and insect species. The findings are expected to provide a consolidated evidence base and support the identification and optimization of processing strategies that preserve or improve the nutritional quality of edible insect proteins for human consumption.

Condition being studied This systematic review focuses on the effects of thermal processing on protein digestibility and protein quality of edible insects intended for human consumption. Thermal processing can modify the structural and physicochemical properties of insect proteins, potentially affecting their susceptibility to digestion, amino acid availability, and overall nutritional quality. Depending on the processing conditions, heat treatment may either improve protein digestibility through protein denaturation and reduction of antinutritional factors or impair protein quality through aggregation, oxidation, cross-linking, and Maillard reactions. This review will evaluate these changes across different edible insect species and thermal processing methods using evidence from studies assessing protein digestibility and/or protein quality.

METHODS

Search strategy A comprehensive literature search was conducted in three electronic databases: PubMed, Scopus, and Web of Science. The search strategy combined terms related to three main concepts: (1) edible insects, (2) thermal processing, and (3) protein digestibility and protein quality. Relevant controlled vocabulary terms, where applicable, and free-text keywords were combined using Boolean operators (AND and OR). Search terms related to edible insects included terms such as “edible insect*”, “insect protein*”, and names of commonly consumed insect species or groups. Thermal processing terms included “thermal processing”, “heat treatment”, boiling, steaming, roasting, frying, baking, grilling, blanching, and other relevant heat-based processing methods. Outcome-related terms included “protein digestibility”, “protein quality”, “protein digestion”, “PDCAAS”, “DIAAS”, and other relevant indicators of protein digestibility and quality. The search strategy was adapted to the syntax and indexing system of each database.

The search was limited to articles published in English between 2016 and 2026. Only publications classified as research articles were considered, while other document types, such as reviews, conference papers, book chapters, editorials, and letters, were excluded. No geographical restrictions were applied. The complete search strategies used for PubMed, Scopus, and Web of Science, including database-specific search terms and filters, will be documented and reported to ensure transparency and reproducibility.

Participant or population At least one recognized edible insect species, any order, life stage, or form, intended for human food or food-ingredient use.

Intervention At least one identifiable thermal process applied before consumption or digestion, with sufficient description to establish a heat-related exposure.

Comparator Raw or unprocessed insect material or an alternative processing method. Studies without a comparator may contribute only to descriptive synthesis.

Study designs to be included Original in vitro digestion studies, animal in vivo studies, or human feeding/clinical studies.

Eligibility criteria Original research articles involving in vitro, animal, or human studies will be eligible for inclusion. Studies must investigate at least one recognized edible insect species intended or relevant for human consumption and apply, describe, or compare at least one clearly identifiable thermal processing method. Eligible studies must evaluate the effects of thermal processing on protein digestibility and/or protein quality. Protein digestibility may be assessed using either in vitro or in vivo methods. For protein quality, the primary measures of interest will be the Protein Digestibility-Corrected Amino Acid Score (PDCAAS) and Digestible Indispensable Amino Acid Score (DIAAS). Other measures of protein quality may also be considered for inclusion when they provide relevant and interpretable information on the effects of thermal processing. Studies must provide relevant digestibility or protein quality outcomes that allow the effects of thermal processing to be evaluated. Only research articles published in English between 2016 and 2026 will be included.

Studies will be excluded if they report only proximate composition, such as crude protein, fat, or fiber content, without assessing protein digestibility or a relevant protein quality outcome. Studies investigating insects exclusively as animal feed without relevance to human food or human nutrition will also be excluded. Studies of insect-fortified or insect-containing food products will be excluded when differences between groups are attributable only to the amount of insect incorporated and do not provide a relevant contrast in thermal processing. Reviews, systematic reviews, meta-analyses, editorials, conference abstracts or proceedings, theses or dissertations, preprints, and other grey literature will not be eligible. Studies that do not provide extractable numerical data or clearly described qualitative findings on protein digestibility or relevant protein quality outcomes will also be excluded. Articles for which the full text cannot be obtained will be excluded from the final review.

Information sources The primary information sources for this systematic review were three electronic databases: PubMed, Scopus, and Web of Science, which were searched up to 8 August 2026. The reference lists of eligible studies and relevant review articles will also be manually screened to identify additional potentially eligible studies that may not have been retrieved through the electronic database searches. Grey literature, conference proceedings, dissertations or theses, preprints, and trial registries were not included as information sources. No direct contact with study authors is planned for the purpose of identifying additional studies.

Main outcome(s) The main outcomes of this systematic review are protein digestibility and protein quality of edible insects following thermal processing. Protein digestibility will include measures of protein digestibility assessed using in vitro and/or in vivo methods, as reported by the included studies. Protein quality will primarily be assessed using established indices, including the Protein Digestibility-Corrected Amino Acid Score (PDCAAS) and/or Digestible Indispensable Amino Acid Score (DIAAS).

Data management Records retrieved from PubMed, Scopus, and Web of Science were exported, merged, and deduplicated before formal screening. The deduplicated records were imported into the screening platform for formal assessment against the predefined eligibility criteria. Title and abstract screening is being conducted independently by two reviewers, and potentially eligible studies will subsequently undergo full-text assessment. Reasons for exclusion at the full-text screening stage will be documented.

Data from the included studies will be extracted using a standardized data extraction form developed in Microsoft Excel. Extracted information will include study characteristics, edible insect species and sample characteristics, thermal processing methods and conditions, comparator groups, methods used to assess protein digestibility and protein quality, and relevant outcome data. The extracted data will be checked for completeness and consistency before synthesis. Records of study selection, eligibility decisions, and extracted data will be maintained throughout the review process to ensure transparency and traceability.

Quality assessment / Risk of bias analysis The methodological quality and risk of bias of the included studies will be assessed according to study design. For in vivo animal studies, the SYRCLE Risk of Bias tool will be used to evaluate potential bias related to selection, performance, detection, attrition, reporting, and other sources of bias. For in vitro studies, methodological quality will be evaluated using a structured appraisal framework adapted to the characteristics of laboratory-based protein digestion and quality studies. The assessment will consider relevant domains, including sample characterization, adequacy and reproducibility of thermal processing conditions, appropriateness of comparator groups, standardization and validity of digestion methods, validity of protein digestibility and/or protein quality measurements, experimental replication, completeness of outcome reporting, and appropriateness of statistical analyses. If eligible human intervention studies are identified, an appropriate design-specific risk-of-bias tool will be applied. Two reviewers will independently perform the assessments, and disagreements will be resolved through discussion or consultation with a third reviewer when necessary. The results will be considered when interpreting the overall findings of the review.

Strategy of data synthesis A narrative synthesis will be conducted to summarize the effects of thermal processing on protein digestibility and protein quality of edible insects. Study characteristics and findings will be presented in structured tables, including insect species, thermal processing methods and conditions (e.g., temperature and duration), comparators, methods used to assess protein digestibility and protein quality, and relevant outcome measures. The direction and magnitude of changes in protein

digestibility and protein quality following thermal processing will be compared with those observed in raw or unprocessed insects or insects subjected to alternative processing methods.
The findings will be synthesized according to relevant characteristics, including insect species, type and conditions of thermal processing, comparator, and methods used to assess protein digestibility and protein quality. Results from in vitro and in vivo studies will be synthesized separately where appropriate because of differences in experimental approaches and interpretation of outcomes. Protein quality outcomes, particularly the Protein Digestibility-Corrected Amino Acid Score (PDCAAS) and Digestible Indispensable Amino Acid Score (DIAAS), will also be summarized across studies. The synthesis will focus on identifying patterns in the direction of effects, including increases, decreases, or no apparent changes in protein digestibility and protein quality following thermal processing. Meta-analysis will not be performed due to the anticipated methodological heterogeneity across studies, particularly in insect species, thermal processing methods and conditions, comparators, and methods used to assess protein digestibility and protein quality.

Subgroup analysis Descriptive subgrouping by thermal-process category, insect species, material/product matrix, comparator type, and outcome method (in vitro versus in vivo; digestibility versus PDCAAS/DIAAS) where sufficient studies are available.

Sensitivity analysis No quantitative sensitivity analysis is planned, as this review will not include a meta-analysis. Narrative sensitivity will consider whether conclusions change when limited to studies with an adequate comparator, clearly described exposure, and sufficiently reported digestion protocol.

Language restriction English-language publications only.

Country(ies) involved Indonesia and South Korea.

Keywords edible insects; thermal processing; protein digestibility; protein quality; PDCAAS; DIAAS; systematic review.

Dissemination plans The completed systematic review will be prepared for submission to a peer-reviewed journal. The INPLASY record will be cited in the final manuscript.

Contributions of each author

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